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SEQUENTIAL USE WITHIN A HYDROLOGIC COMPLEX

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15 March 1967

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FWPCA, OHIO BASIN REGION
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First Annual Progress Report

FWPCA Demonstration Project WPD 17-01(R1)-66

SEQUENTIAL USE WITHIN A HYDROLOGIC COMPLEX

Grantee Institution: Utah State University

Project Director: David W. Hendricks, Assist. Prof.

Report Period: December 1, 1965 - March 31, 1967

Date of Report Preparation: March 15, 1967

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2. Summary Statement

The primary objective of the first year of operation of the project was to delineate the system in terms of model building requirements for a hydrologic-quality model. As implied by this objective, it was necessary to define the hydrologic and water quality characteristics of the system. This was done: (1) by collecting and collating previous data and reports, and (2) by implementing a data collection program to augment previous work. This included hydrologic and water quality data.

The secondary activity of the first year was in formulating plans for the model building phase of the project, which will be the principal activity during the second year.

Details of illustrations in
this document may be better
studied on microfiche.

3. Statement of Progress

A. Activities and Accomplishments

Introduction

The objective of the second phase of the project is to build a hydrologic-quality model that will simulate the prototype stream quality system in time and space. Toward this end, the first phase of the project has been oriented primarily toward collecting adequate data to describe the prototype hydro-quality system, and to utilize the data in such a model. This has been done by implementing a data monitoring system and by collecting and collating previous data and reports. The data monitoring system consists of a network of hydro-quality stations to describe (a) streamflow, (b) water quality parameters, and (c) climatic factors.

The philosophy of the model, and hence the data acquisition and monitoring policy, has been to utilize the mass balance principle to assist in describing the hydrologic-quality system, as a system. This includes following the flow system through a sequence of uses to account for changes occurring in quantity and quality.

Specific activities toward this objective and the relationship of each activity to the project are described subsequently. Project activities are categorized in the following summary.

Activities Summary

Precipitation and temperature. To correlate stream quality with precipitation, weather stations, located in the project area, were felt desirable. Two weather stations were located in the project area, last fall, to serve until permanent telemetry weather stations were installed by another UWRL project (on weather modification). Fig. 1 shows the locations of the telemetry stations; those in the project area that have just recently become operational or pending operational are underlined. The Weather Modification project gave some priority to making operational the stations in the "Sequential Use" project area. The data from these stations are transmitted to a central receiving station at the UWRL. These data are and will be available on call, which is a daily routine.

Temperature data are also available from the weather stations. This measurement will be used in estimating evapotranspiration, in assessing the form of precipitation, and in correlating with snowmelt.

Precipitation and temperature data have been collected at Logan since 1891[1/]. The Logan records will be useful in giving the historical patterns of precipitation and temperature.

Streamflow and canal flows. The USGS has operated four gaging[2/] stations on the Little Bear River system prior to this project. By contract agreement with this project, they installed and are operating,

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[1/] U. S. Weather Bureau, Climatological Data, Utah. Vol. 1 - 68, 1898 - 1966, plus 1891 - 1897.

[2/] U. S. Geological Survey, Water-Supply Papers--The Great Basin. 1927 - 1965.

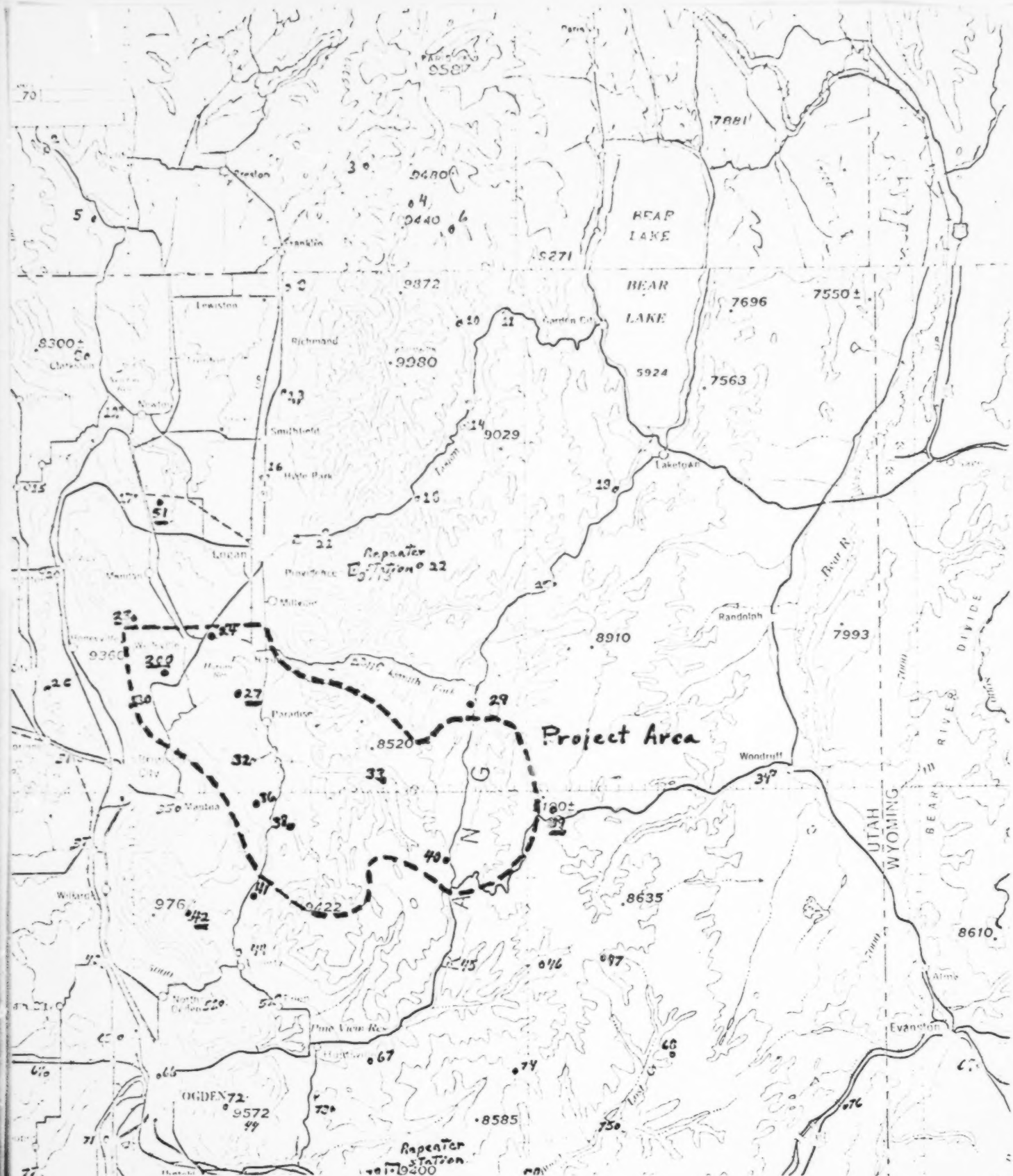

Fig. 1. Location of weather telemetry stations in project area and in Wasatch Mountains. Underlined stations are operational.

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since July 1, 1966, four additional stations; two of these stations are located on the Little Bear River system and two are located on canals. The four additional stations are located at critical points in the system in order to complete the mass balance picture of the surface flows, as a part of the total hydrologic entity. These data are made available to the project at quarterly intervals and are stored on punched cards. The locations of the gaging stations are shown in Fig. 2.

The gaging of canal systems, at the beginning of the canal, is the responsibility of the canal companies through an appointed water commissioner. The canal flows are available through the annual water commissioner's report[3/]. Reservoir levels are also available in this report.

The surface water flow and storage in the Little Bear River system are felt to be adequately delineated by the present gaging system for use in the model building phase.

Evapotranspiration. The water applied to the irrigated acreage in the Little Bear River system is used partially by evapotranspiration, with the balance returning to the stream system by interflow or groundwater flow. The seasonal pattern and magnitude of the evapotranspiration has been estimated by standard procedures based upon climatic data and irrigated acreage. Assessing the irrigated acreage and other acreage was one of the activities of the previous summer. All irrigated and other acreage receiving water in excess of natural precipitation was classified. This again is an integral part of the

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3/ Little Bear River Commissioner, Annual Report of Little Bear River Distribution System. 1962 - 1966.

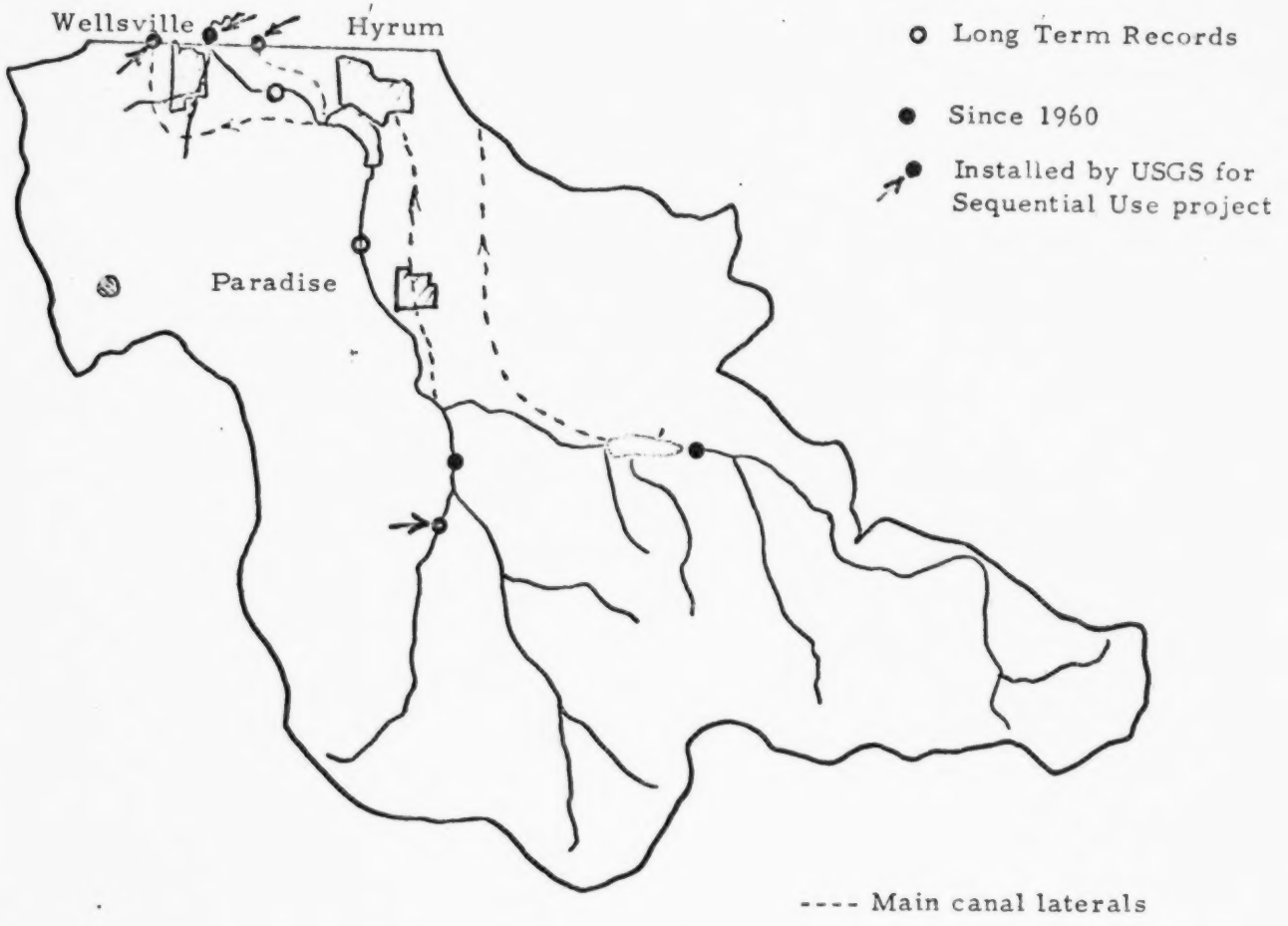

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Fig. 2. Locations of stream and canal gaging stations, Little Bear River system.

description of the hydrologic system. This also relates to the quality system from the standpoint of salinity accumulations, which will be considered in the systems description.

Groundwater. The storage and flow of groundwater is, of course, difficult to evaluate quantitatively, but it is an intrinsic part of any hydrologic system, and especially this system. In the Hyrum-Wellsville area, the groundwater table is close to or at the surface and there is good basis for believing that return irrigation interflow back to the Little Bear River system is substantial. This is corroborated by field surveys, conducted in the area with a seismograph, during the previous summer, to determine the general locations of the water table and bedrock. Generally, a hard "impervious" layer was found on the order of 30 ft. depth below the surface, although in some areas the impervious layer was not detected. Thus, the hydraulic gradient is in the direction of the stream system. Some attempt will be made during the coming year to quantitatively assess groundwater pickup by inflow-outflow measurements. This has an important bearing on the salinity increase observed on the stream in the downstream direction.

Water quality. Several sampling stations were set up on the Little Bear River system to monitor water quality, on a weekly basis. The weekly sampling period appears to be adequate, without oversampling. This is an important consideration from the standpoint of mutual compatibility of different categories of measurements. The locations of these stations are shown in Fig. 3. Again, these stations were placed

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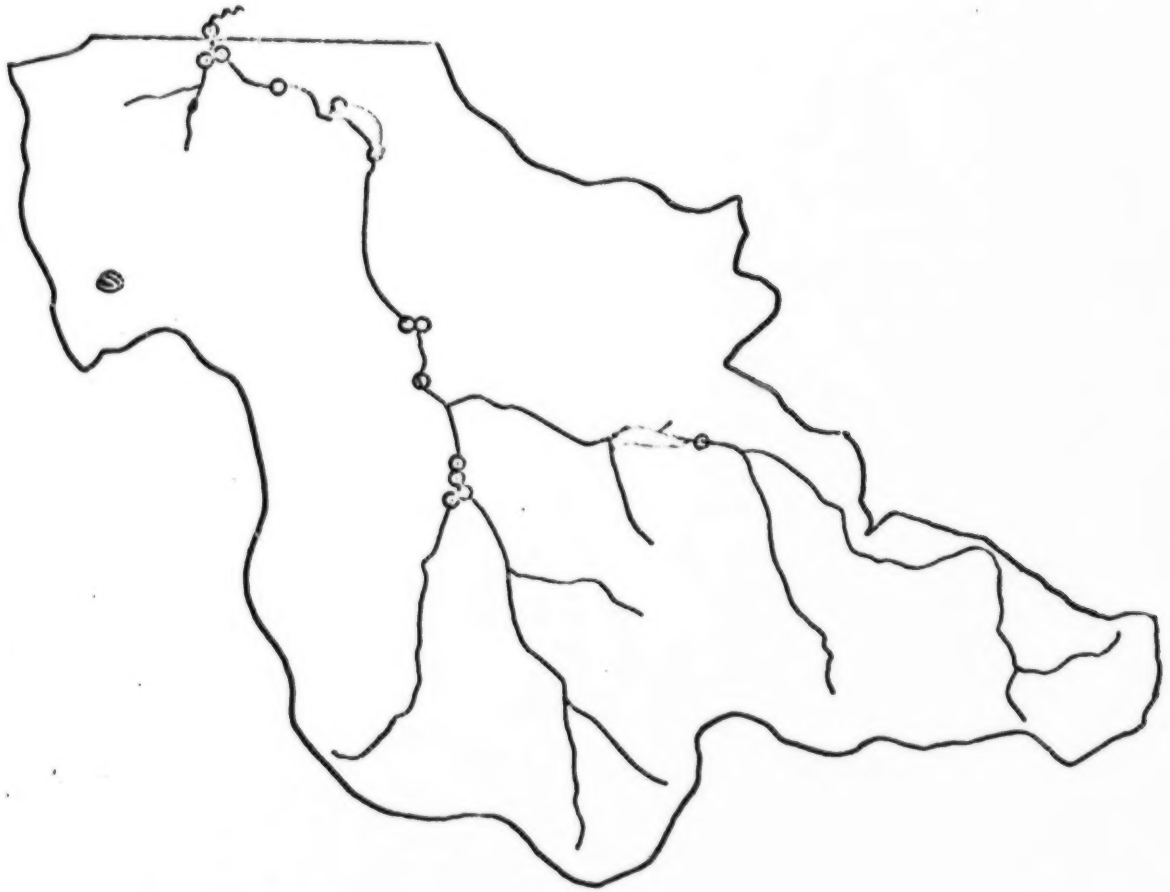

Fig. 3. Locations of sampling stations on the Little Bear River system.

at strategic locations. Some groundwater sampling was also done, on an intermittent basis. Quality parameters measured included coliforms, total count, BOD, TDS, pH, nitrates, phosphates, turbidity, and a number of cations and anions. The water quality sampling program was started in May 1966 and will continue for the duration of the project. These data are also stored on punched cards. The information, together with hydrologic data, will be used in the mass balance model of the system, and in synthesizing deterministic relationships, for each quality parameter.

In addition to the weekly sampling, three continuous monitoring, battery operated, quality stations were to be set up. It was felt, however, that in view of the questionable performance of some of these instruments, and the rapid improvements that are currently being made, the best selections would be made by deferring purchases until all information from all manufacturers could be gathered and assessed. This has been done and purchase orders on instruments to measure dissolved oxygen, temperature, pH, and electrical conductivity have been issued, and the instruments are currently being shipped. One such instrument tested this month in a laboratory channel, over a ten day continuous period, showed excellent stability with negligible drift in the dissolved oxygen measurement and zero drift in the temperature measurement. Since to obtain good, reliable instruments is somewhat more expensive than that budgeted originally, only two

stations will be set up instead of three stations. The purpose of these continuous monitoring instruments is not to increase the mass of data, but to assess diurnal quality changes and to monitor changes in the system that might well be missed by the weekly sampling. This will allow some evaluation of intermittent waste inputs, and diurnal changes in certain quality parameters.

There is one previous report[4/] containing some data on water quality of the Little Bear River. This information was collected during a Utah Water Pollution Control Board survey of the Lower Bear River.

Model Building

This was an activity during the first year but not in a major way. There has been some thought and preparation in this direction, however. A project library on hydrologic, quality, and water management models as well as operations research techniques applied to such models is currently being acquired. Both analog and digital computers will be used to accomplish the project goals. The initial model or models of the hydro-quality system will be programmed and verified on the UWRL analog computer. Frequency analysis of stochastic variables will be done on a digital computer and these results will be used to define various input conditions of the previously verified analog model. The sequential effects of the various water uses will be analyzed by operational research techniques to obtain optimal solutions for various quality criteria.

4/ Ward, John A., and Clarence M. Skoubye, "Chemical Quality and Flow Measurements of the Waters of the Bear River System in Cache County and Box Elder County, Utah, 1958-59," Utah State Water Pollution Control Board.

The entire system may be envisioned as a layered set of single parameter models, each a representation of the continuity equation, with the foundation or underlying layer being the hydrologic model. The hydrologic model is shown schematically in Fig. 4 and represents the initial model which will be programmed and verified on the analog computer. Transfer and storage functions represented by the boxes and interconnecting lines in Fig. 4 have been developed in conjunction with other research in progress at the UWRL but the actual verification of them is awaiting completion of the analog computer program and some necessary data reduction to apply them to the Little Bear River Watershed. The hydrologic model shown in Fig. 4 is quite general in that it is applicable to any size space and time increment. The first model to be developed will consist of two space or geographic increments, one being the high elevation mountainous watershed area and the other being the valley area where the primary resource development will take place. If this incrementation does not prove adequate it will be increased until sufficient refinement is obtained.

A quality model for each of the pertinent quality parameters will be very similar to the hydrologic model shown in Fig. 4 in that each will also represent the continuity equation schematically. A mass balance model for each quality parameter will be developed and verified individually. An example of this type model for total dissolved solids (TDS) is shown in Fig. 5. After each model has been sufficiently refined and verified, the entire set will be combined in a complete

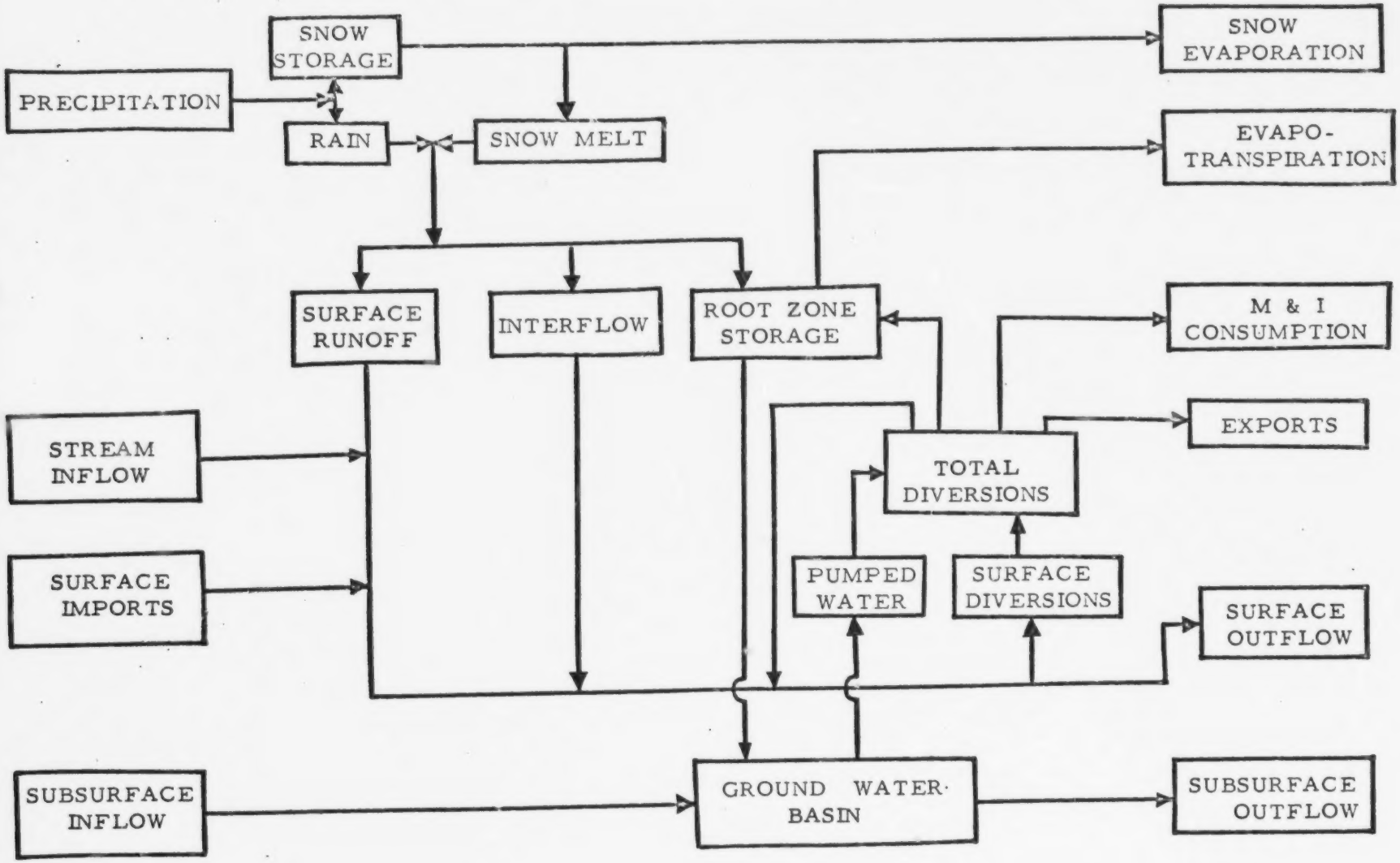

Figure 4. General hydrologic model of a water resource system.

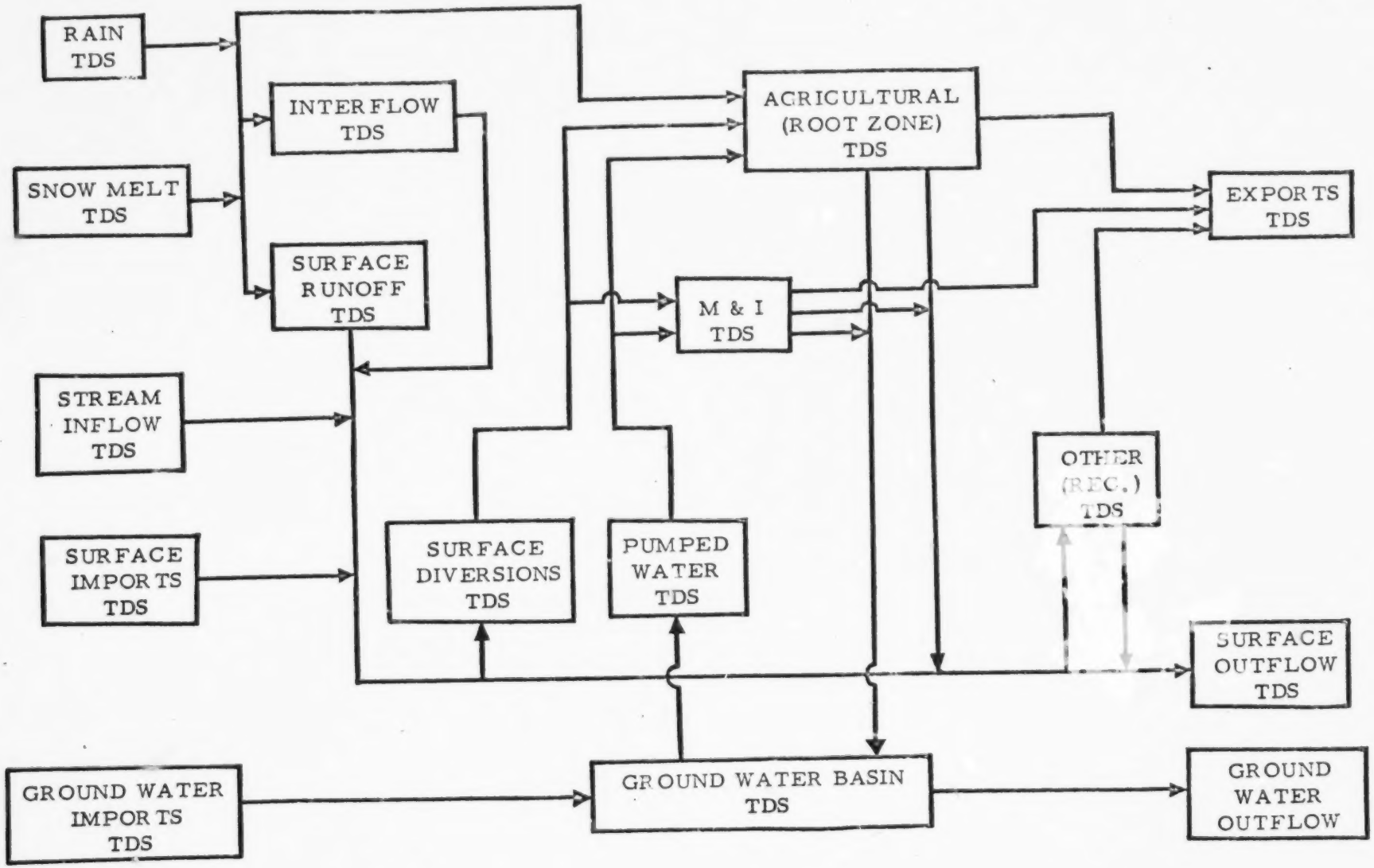

Figure 5. General total dissolved solids (TDS) model of a water resource system.

system. The space and time increments used in the final system model must be compatible and will be governed by the particular parameter that required the largest number of increments to provide adequate modeling. Although each of the individual models will initially utilize only two space increments and coarse time increments, it is anticipated that these will have to be changed in order to evaluate the full sequential significance of the system. Therefore, a substantial amount of work may be required to develop the transfer functions to adequately describe the spatial variations of reduced space increments. The final model will probably have as many space increments as the capacity of the analog or digital computer will allow. The limitation on the time increment will not be governed as much by equipment considerations as by solution time on the computer. The smaller the time increment, the longer it will take to solve the problems.

After a suitably refined model of the system is obtained the next step will be to develop the capacity to optimize the system with respect to quality parameters and quality constraints. The analytic techniques of dynamic programming and linear programming as well as the method of simulation will be investigated as to their applicability to this phase of the project. The analytic techniques will be done only on a digital computer whereas simulation may be done on both types of computer, analog and digital. If time and money are available, the system may be enlarged by adding the economic constraints as another

layer, and thus apply optimization techniques with respect to this part of the system. Likewise, the legal aspect may later be added, at which time the utility of the systems approach as a management tool will be evident. The development and treating of the various models described above will be the major effort during the second year.

Accomplishments

The above activities for the past year have resulted in the system being reasonably well defined, consistent with the objectives of the project. Therefore, the first phase objective of the project has been accomplished.

Also contacts have been established with state agencies who have responsibilities in water quality planning. There is interest in the project from the standpoint of establishing procedures in water resource planning in the quality dimension.

B. Significant Problems

There were no major unforeseen problems that have caused deviations from the project plan as approved.

C. Project Staff

(1) H. Millar, Research Chemist, Sept. 1966 - present

- Supervises laboratory and works out methods (40%)

(2) D. Hendricks, Assistant Professor, Sanitary Engineering, Dec. 1965 - present

- Project Director (Project co-investigator until Sept. '66) (50%)

(3) J. Bagley, Director, UWRL, Dec. 1965 - present

- Project Consultant (Project Director until Sept. '66) (20%)

(4) L. Huber, Research Engineer, July 1966 - present

- Developing systems model and computer programming (15%)

(5) E. Israelsen, Research Engineer, March 1966 - present

- Responsible for field data collation and analog modeling (20%)

(6) F. Post, Bacteriologist, Jan. 1966 - present

- Supervises bacteriological work and project consultant (15%)

Published Reports and Articles

None

SECTION II - PRIVILEGED COMMUNICATION

3. BIOGRAPHICAL SKETCHES

(Give the following information for EACH key staff member, beginning with the Principal Investigator. Use continuation pages and follow the same general format for each person.)

NAME	TITLE	BIRTHDATE (Mo., Day, Yr.)
H. C. Millar	Research Chemist	11/24/07
PLACE OF BIRTH (City, State, Country)	**PRESENT NATIONALITY (If non-U.S. citizen, indicate visa status)**	**SEX**
American Fork, Utah, USA	U.S.	☒ Male ☐ Female

EDUCATION *(Begin with baccalaureate training and include postdoctoral)*

INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED
Brigham Young University, Provo, Utah	B.S.	1931
Brigham Young University, Provo, Utah	Ed. Admin.	1932
Iowa State University, Ames, Iowa	M.S.	1934
Iowa State University, Ames, Iowa	Ph. D.	1936
University of Chicago, Chicago, Illinois		1943
University of California, Berkeley, California		1946
Utah State University, Logan, Utah (Studies in Toxicology Curriculum)	Post Doctoral	1964-66

HONORS

Awarded Research Fellowship--1933 - 1936
Sigma Xi--1936
Gamma Sigma Delta--1936

MAJOR RESEARCH INTEREST

1. Toxicology of our environment in relation to man and his food
2. Water Pollution - Methods of Appraisal Air Pollution - Methods of Appraisal
3. Methods of Chemical Analysis by Instrumentation

RELATIONSHIP TO PROPOSED PROJECT

Research Chemist assigned to Project WG-37

RESEARCH AND/OR PROFESSIONAL EXPERIENCE *(Start with present position, list ALL experience relevant to project.)*

1966 - present	Research Chemist - Utah Water Research Laboratory
1964 - 1966	Post Doctorate Fellowship in Toxicology Curriculum Polynuclear Hydrocarbons as Carcinogens and Teratogenic Agents on the Chick and Mice Embryos
1947 - 1964	President of Geneva Food and Chemical Corporation (Agricultural Chemicals)
1945 - 1947	Patent Chemist, California Research Corporation Oronite Chemical--Subsidiary of Standard Oil Co. of California
1936 - 1945	Research Chemist - The Quaker Oats Company Chemicals from and Commercial Utilization of Agricultural Wastes and By-Products

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NAME	TITLE	BIRTHDATE *(Mo., Day, Yr.)*
Eugene K. Israelsen	Assistant Research Engineer	June 28, 1936
PLACE OF BIRTH *(City, State, Country)*	**PRESENT NATIONALITY** *(If non-U.S. citizen, indicate visa status)*	**SEX**
Hyrum, Utah, USA	US	☒ Male ☐ Female

EDUCATION *(Begin with baccalaureate training and include postdoctoral)*

INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED
Utah State University, Logan, Utah	B.S.	1962

HONORS

MAJOR RESEARCH INTEREST

Water Resources and Simulation of Water Resource Systems

RELATIONSHIP TO PROPOSED PROJECT

(1) Oversees field work, (2) data collation, and (3) modeling

RESEARCH AND/OR PROFESSIONAL EXPERIENCE *(Start with present position; list ALL experience relevant to project.)*

Assistant Research Engineer, Utah Water Research Laboratory, 1965 - present

1. Hydrologic simulation Walnut Gulch, Arizona, and Reynold's Creek, Idaho.
2. Land-use study including the Little Bear River Area.

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